TECHEVON LLC
METAL FINISHING SOLUTIONS

Anodizing Armament/Firearm Components – Factors and Features to Consider in the Anodizing Finish

Presented By:

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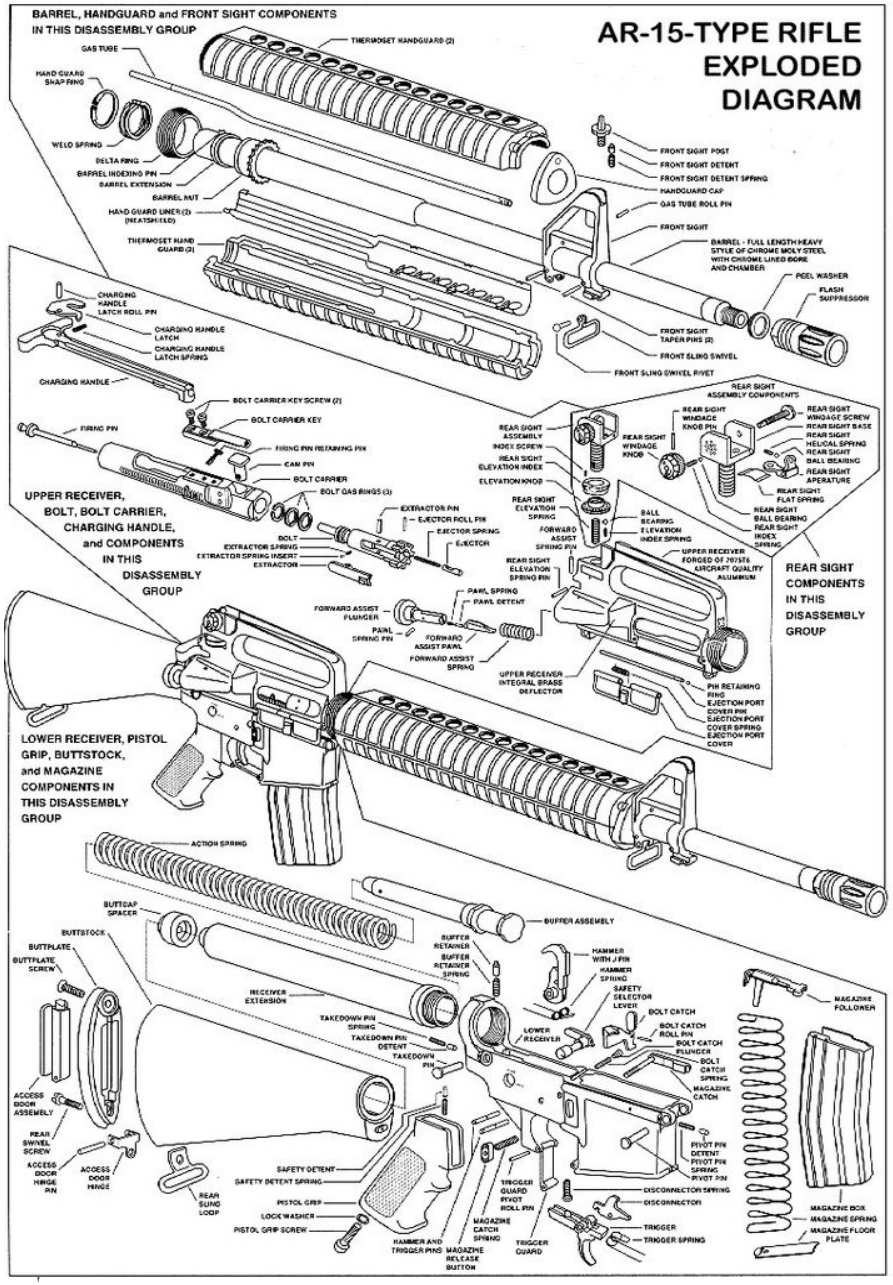
Objective

- This paper will provide an overview of the anodizing industry as it relates to firearm components and end user expectations for color, finish, uniformity and durability. Specifically factors such mechanical pretreatment and subsequent chemical pretreatments prior to anodizing will be discussed.
- Furthermore the paper will provide information on how to address galvanic corrosion as it relates to alloys, tooling, dye chemistry and other operating conditions.

Agenda

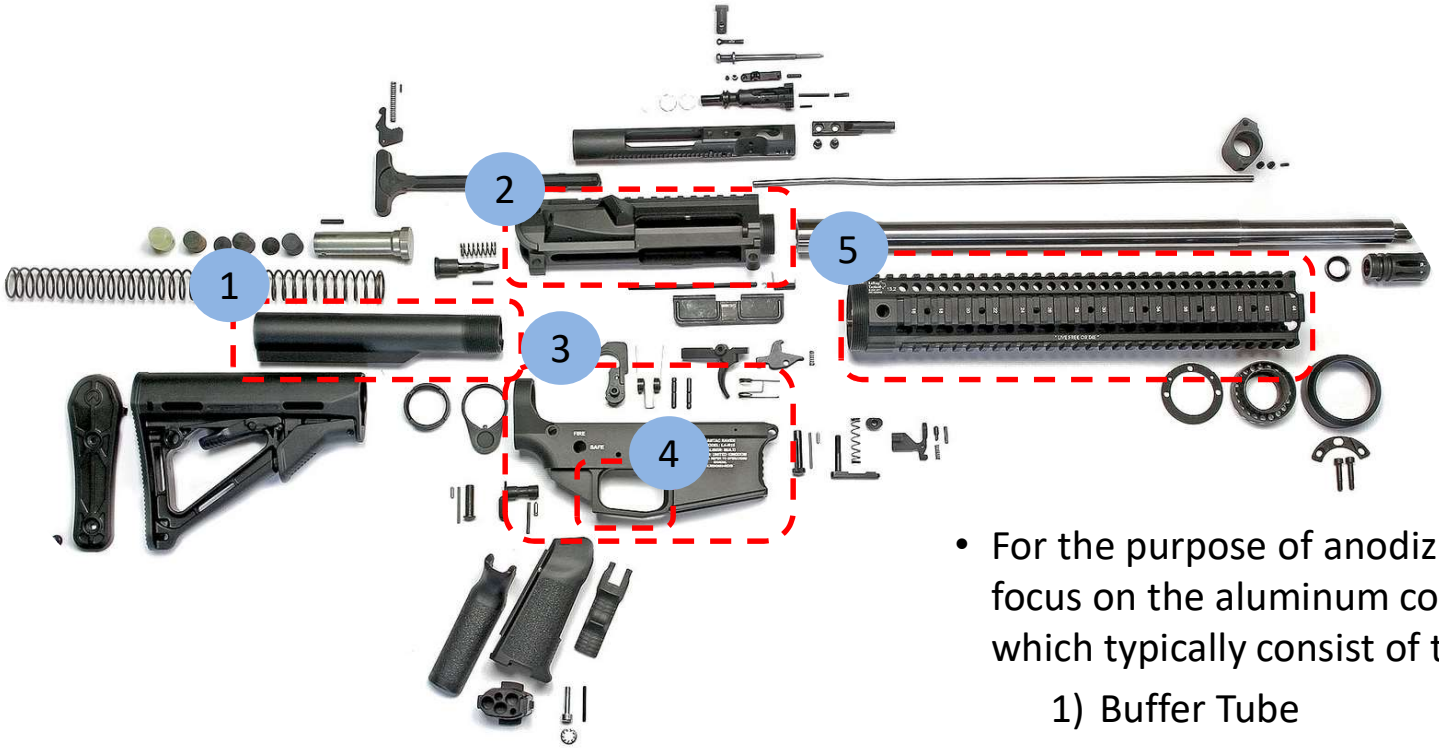
- Overview of Firearm Components and Applications
- Functional Requirements
- Technical Requirements
- Anodizing Factors to Consider
  - Pretreatment
  - Anodizing
  - Dyeing
  - Sealing
- Other Factors to Consider
- Common Issues/Challenges
- Final Thoughts

Overview of Armament Components and Applications



- In general firearms are comprised of multitude of components that are assembled to create a functional weapons system.
- For example on the diagram to the left a diagram of a fully dis assembled AR-15 rifle consists of over 70 sub components that must all match in color and durability where possible
- Due to the nature of their use firearms require the following features:
  - Durability in extreme temperatures, sunlight, and handling
  - Reliability of effective operation when called into service
  - Consistent color

Overview of Armament Components and Applications



- For the purpose of anodizing scope we will focus on the aluminum components only which typically consist of the following:
    1) Buffer Tube
    2) Upper Receiver
    3) Lower Receiver
    4) Handguard/Trigger guard
    5) Rail
- These components make up the majority of anodized parts for the anodizing industry and require the most attention to detail for finish and color consistency

Functional Requirements: Type of Coating

Coating Type	Description	Advantages	Disadvantages
Gun Bluing/ Black Oxide	• Process which is used to give a rust resistant finish by an electrochemical process where the iron in steel is converted to magnetite, or black oxide.	• No dimensional change • Decrease glare effect	• Minimal rust protection and requires oiling
Parkerizing/ Phosphating	• Process where steel part is submersed into a heated phosphoric acid solution that contains zinc or manganese and/or copper. This creates a conversion coating on the surface of the metal.	• Corrosion resistance	• Color variability • Requires 2nd coating such with molybdenum for lubricity • Requires oiling
Anodizing	• The anodizing process increases the thickness of the natural aluminum oxide layer on the surface of a metal piece through the application of current in an electrolyte solution	• Increased lubricity and hardness • Improved adhesion for surface paint or primers • Corrosion resistance	• Changes dimensional sizes • Alloy color variability
Cerakote	• Process where a ceramic coating is applied to the surface of the material. Cerakote requires little maintenance and will last you for years before needing a touch-up.	• Multiple color options • Heat resistant up to 1,000 F • Superior lubricity • Can be applied to metals, plastic and composites	• Very expensive
Nickel Boron/ Electroless Nickel	• Process of applying nickel boron to surface without use of electrical current by immersing into a solution containing sodium borohydride/alkylamine borane	• No electrical current required • Can be applied to stainless steel, aluminum and titanium	• Requires some lubrication oil • Glare effect when buffed
Ferritic Nitro-carburizing	• Process that introduces nitrogen and carbon into steel or another iron-containing alloy.	• Enhanced scratch resistance • Decrease thermal shock and distortion on metal	• Less corrosion resistance compared to other coatings
Quench Polish Quench (QPQ)	• Process is more effective version of ferritic nitrocarburizing but includes a polishing process and re-immersion into to increase the corrosion resistance by creating a layer of iron oxide.	• Increased corrosions/ wear resistance	• Requires additional process steps

Functional Requirements

- There are a number of requirements that the military sets forth in order to ensure that their weapons systems can function in an operating environment.
- Some of these requirements include the following
  - Ergonomic design
  - Light weight
  - Heat fastness
  - Light fastness
  - Reliability
  - Consistent color/finish
  - Ease of assembly
- Due to the nature of their use, military firearms require a robust/standardized process to ensure that all of the above functional requirements are met as it relates to the anodizing process
- The specification that is referenced for the anodizers is the Mil-Spec-8625F, which does not go into the pretreatment conditions and the shade of dye, which impact the appearance of the final product.

Technical Requirements

Mil 8625 is the most common referenced specification for armament components that are anodized North America.

There are 3 types of coatings for the Mil 8625 Spec:

- Type I - Chromic acid anodizing
  - Dyed or un-dyed
  - Used for best fatigue resistance and pre-paint
- Type II: Conventional Sulfuric Acid
  - Class 1 clear
  - Class 2 dyed
  - Used for protection, aesthetics, non-conductivity
- Type IIB: Thin Sulfuric Acid Anodizing
  - For use as a non-chromate alternative for Type I and IB coatings
- Type III: Hard Coat
  - Abrasion Resistance

Technical Requirements

For sealing the following specification details are provided:

> ***Mil 8625 version F, Sept 10, 1993, Amendment 1, Sept 15, 2003 states "Type I, IB, IC, II, IIB, shall be completely sealed unless otherwise specified… in accordance with 3.8.1.1 or 3.8.1.2 as applicable. If wetting agents are used, they shall be of the non-ionic type."***

- Therefore anodizers using a mid temperature seals are in non-compliance to Mil 8625 because mid temperature seal chemistry uses anionic surfactants to manage smut and other deposits from the sealing tank.
- Additionally, most if not all of the hot nickel acetate seals supplied in the market contain anionic surfactants and using such products could also be a non-conformance, if parts are certified to Mil-Spec 8625 F

What does non compliance mean to an anodizer?

- This seal surfactant issue has become a problem for anodizers who are audited for compliance to the Mil 8625 F certification. There are reports of companies losing NADCAP accreditation until the company is confirmed as compliant.

Anodizing Factors to Consider: Overall

Factor	Unique Considerations for Firearm Components
Incomplete specification	• No specification to cover all aspects of the finish • The specification is designed as a performance requirement which does not address aesthetics of the coating but instead the hardness, thickness and corrosion resistance
Process condition variability	• Anodizers have different process conditions particularly the pre treatment and type of black dye used that can effect the consistency of the final product assembled.
Multiple vendors involved	• Finished product processed by various vendors • This is more critical because there are multiple suppliers who machine the components for the OEM and these machine shops use various anodizers who have their own processes and chemicals and dyes for anodizing these components.

Anodizing Factors to Consider: Pre Treatment

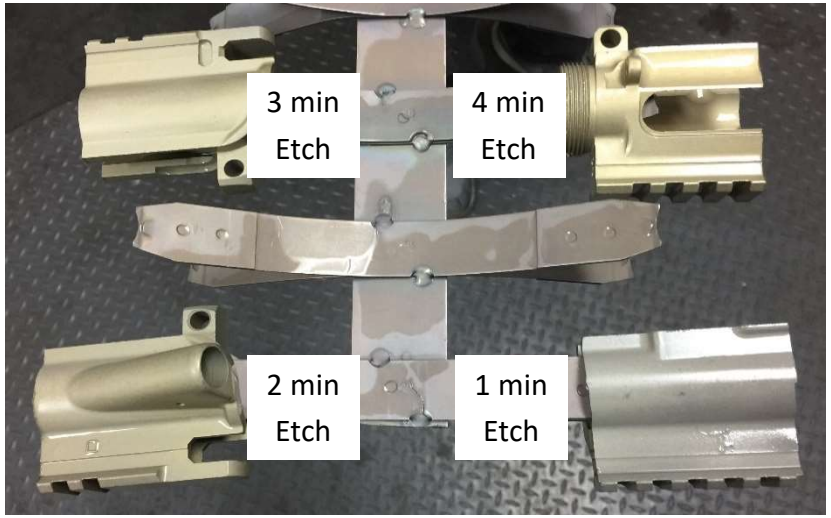
Pre Treatment Process	Purpose	Unique Considerations for Firearm Components
Mechanical	• Remove blemishes and other surface contaminants • Create a rough surface that scatters light	• The media used and duration of blasting can change the exterior characteristic significantly as it relates to uniformity and streaking on the part
Cleaner	• Remove machining oils • Remove shop handling oils	• Machined components may have buffing compounds which are difficult to remove • Certain cleaners may leave a film on the aluminum which is not desirable for the end customer
Etch	• Remove natural oxides • Provide a satin matte finish • Clean surface for anodizing	• Depending on the type of mechanical pre treatment used a longer etch can make a part less visually appealing • Etch time and concentration is critical to achieving the desired finish
Deox/DeSmut	• Remove oxide scale from surface • Remove any other residual chemicals formed during etching • Clean the surface of aluminum for anodizing	• Based on the aggressiveness of the etch solution used a longer deox/desmut maybe required • Additionally in some cases a Deox with some etching capability may help improve the finish

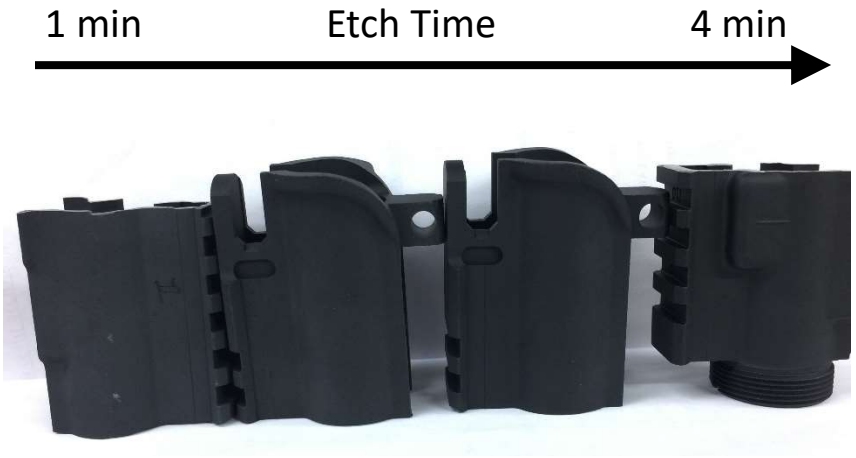
Anodizing Factors to Consider: Pre Treatment Examples

Examples of Inconsistency of Mechanical Treatment

Difference between an original weathered finish, dry media blasting and a vapor blasted finish.

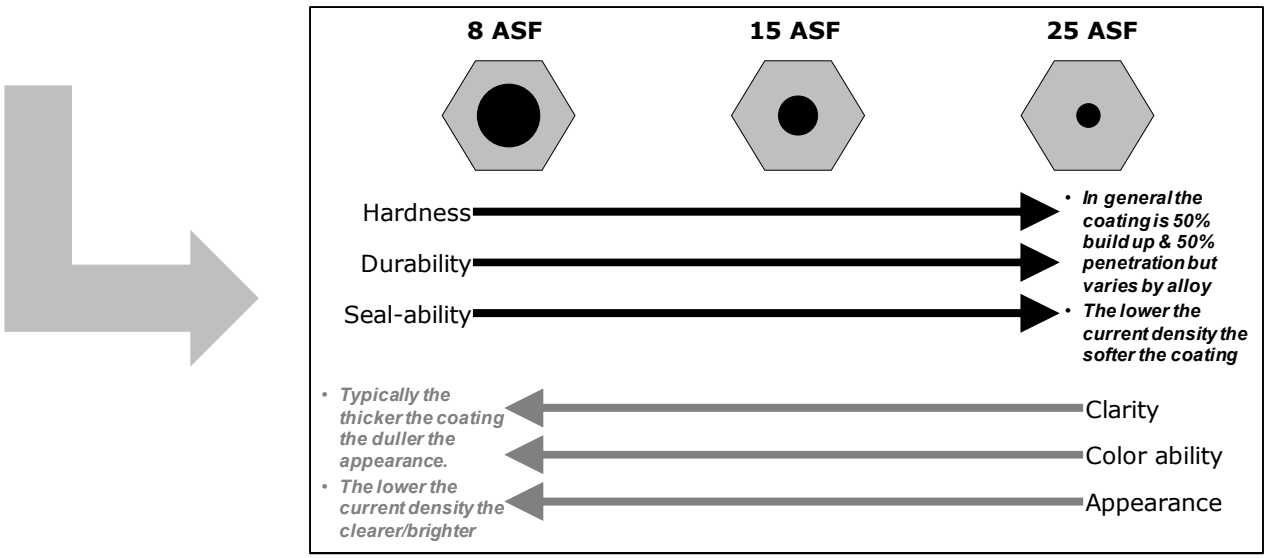
Examples of effect of different pretreatments





Anodizing Factors to Consider: Anodizing

Parameter	Typical Specification	Unique Considerations for Firearm Components
Bath Chemistry	• Convention Hard Coat or Modified Hard Coat	• A modified hard coat tank allows for the use of Titanium racking which reduces rack strip time
Temperature	• 32°F for conventional hard coat • 45°F – 65°F for modified hard coat	• In order to achieve higher temperatures and improved hardness additives must be used in the anodizing tank
Current/ Coating Density	• 25 Amps per square foot	• Hardness is critical therefore a higher density is required but this affects color ability therefore you can reduce the current density on top most layer of the coating to provide an aesthetic benefit
Coating Thickness	• 1.0 mils - 1.5 mil	• The thinner the coating the harder the coating therefore keeping the coating near 1.0 mil. is desirable. The thinner the coating the more flexibility with re work



Anodizing Factors to Consider: Anodizing Examples

Effect of Anodizing Conditions and Thickness

Anodizing Factors to Consider: Dyeing

- Recently the requirements for consistent color particularly with black and tan anodized parts has become very critical for gun components. We have seen a shift in the industry where black dyes that have particularly a red undertone do not meet the specifications of the end customer

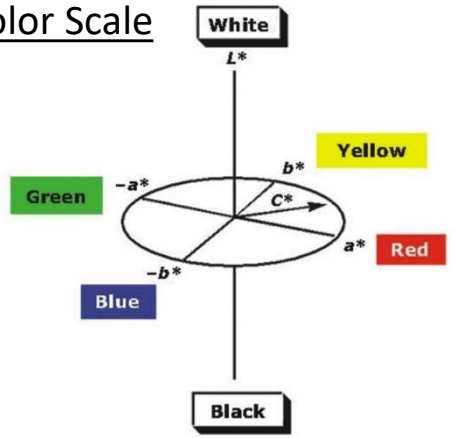
Dye Type	Undertone	Heat Fast	Conventional Anodize	Hard Coat	Alloy	Consistency over Time	Metamerism
Black 	• Blue • Green • Red • Neutral	• Low • Moderate • High	• Molecule Size • Coating Thickness • Contamination	• Molecule Size	• 7075 Alloy will provide a yellow shade that must be offset with a green shade to achieve a neutral black	• Mixtures • Symmetric • Asymmetric	• Not applicable for black dyes
Tan 	• Yellow • Orange	• Low • Moderate • High	• Current Density Effect	• Muted shades with Modified Hard coat	• Shade and color can vary with the same dye between 6061 and 7075	• Single Component • Multi component	• Grey & Brown dyes are most metameric

Anodizing Factors to Consider: Dyeing Examples

Examples of Different Black Dyes

Dye	Darkness Scale (L)	Green-Red Scale (a*)	Yellow-Blue Scale (b*)	Comments
Black 1 (Standard)	24.831	-0.834	-2.05	• Common Industry Black Dye
Black 2 (Neutral Black)	24.119	-0.120	-1.215	• Darker • Less Green • Less Blue • Duller
Black 3 (Blue Black)	25.488	-0.031	-1.413	• Lighter • Less Green • Less Blue • Duller
Black 4 (Red Black)	27.067	0.318	-1.962	• Lighter • Less Green • Less Blue • Duller

Color Scale

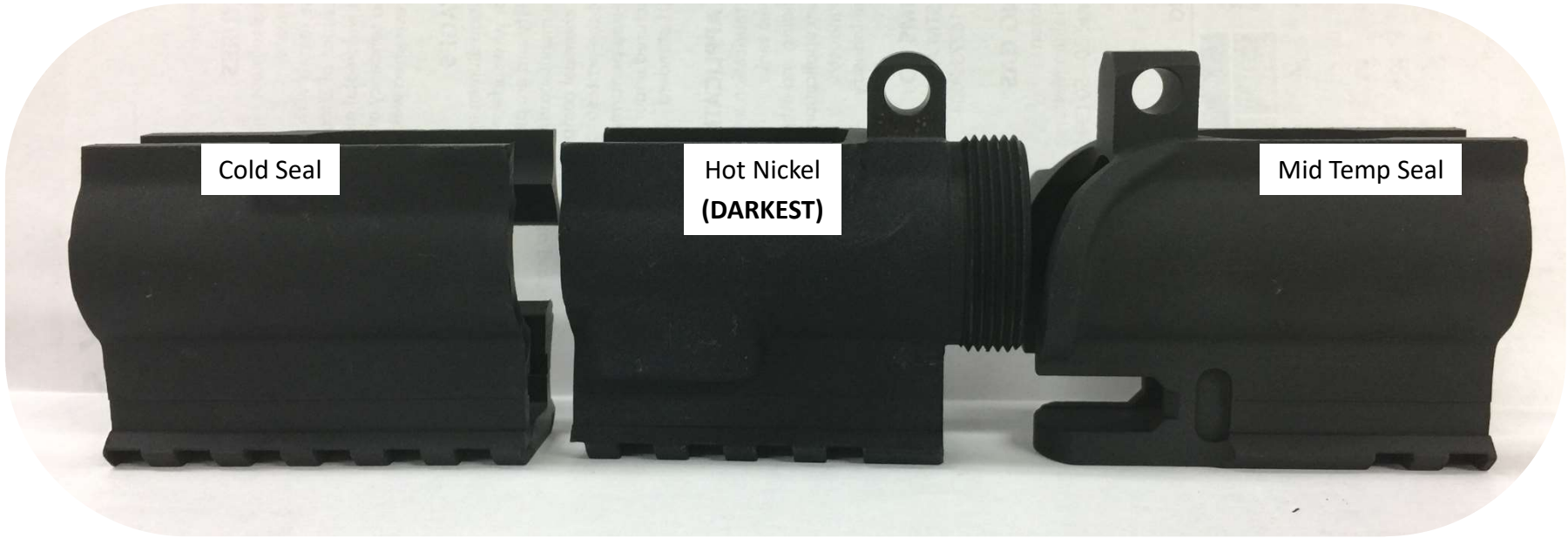


Anodizing Factors to Consider: Sealing

Parameter	Description	Unique Considerations for Firearm Components
Seal Chemistry	• Mid Temp Seal Mil Spec Compliant • Cold Seal with Hot Water Rinse	• When using the Cold Seal do not use air agitation as this will cause smut and follow up with a Hot Water rinse with a smut reduction additive
Temperature	• Mid Temperature Mil Spec Compliant • Cold Seal (>90F)	• The Cold Seal chemistry is completely Mil Spec compliant however not all Mid Temp Seals are due to the use of anionic surfactant.
Immersion Time	• 15 min seal followed by 5 min rinse in the case of Cold Seal	• Immersion time is critical to ensure the coating durability is maintained. In general the lower the coating thickness the easier it is to seal

Anodizing Factors to Consider: Sealing Examples

Effect of Sealing Methods



Other Factors to Consider: Alloy Variations

- There are 2 primary alloys used for varying components on a gun. Each alloy has different anodizing properties that must be considered when trying to anodize and color the parts.

Alloy Series	Alloy Constituents	Anodic Coating Characteristics	Unique Considerations for Firearm Components
6000	• Magnesium • Silicone	• Dull Grey • Good Protection	• Parts can show graining effects if over etched. • Tan color is very difficult
7000	• Zinc	• Yellow Shade • Good Protection	• Higher coating thickness can make the coating very yellow making it difficult to get a tan finish.

Other Factors to Consider: Alloy Variation Examples

Examples of Alloy Variation and Color Change

- As seen the picture to the left the components
  1) Buffer Tube
  2) Upper Receiver (7000 series)
  3) Lower Receiver (7000 series)
  4) Handguard/Trigger guard
  5) Rail (6000 series)

Common Issues/Challenges: Inconsistent Finish

- An inconsistent finish can result from any of the following:
  - Pretreatment variations
  - Alloy type
  - Dye type
  - Anodizing parameters
- The most common reasons for an inconsistent finish are primarily found in the pretreatment. Specifically in the following areas:

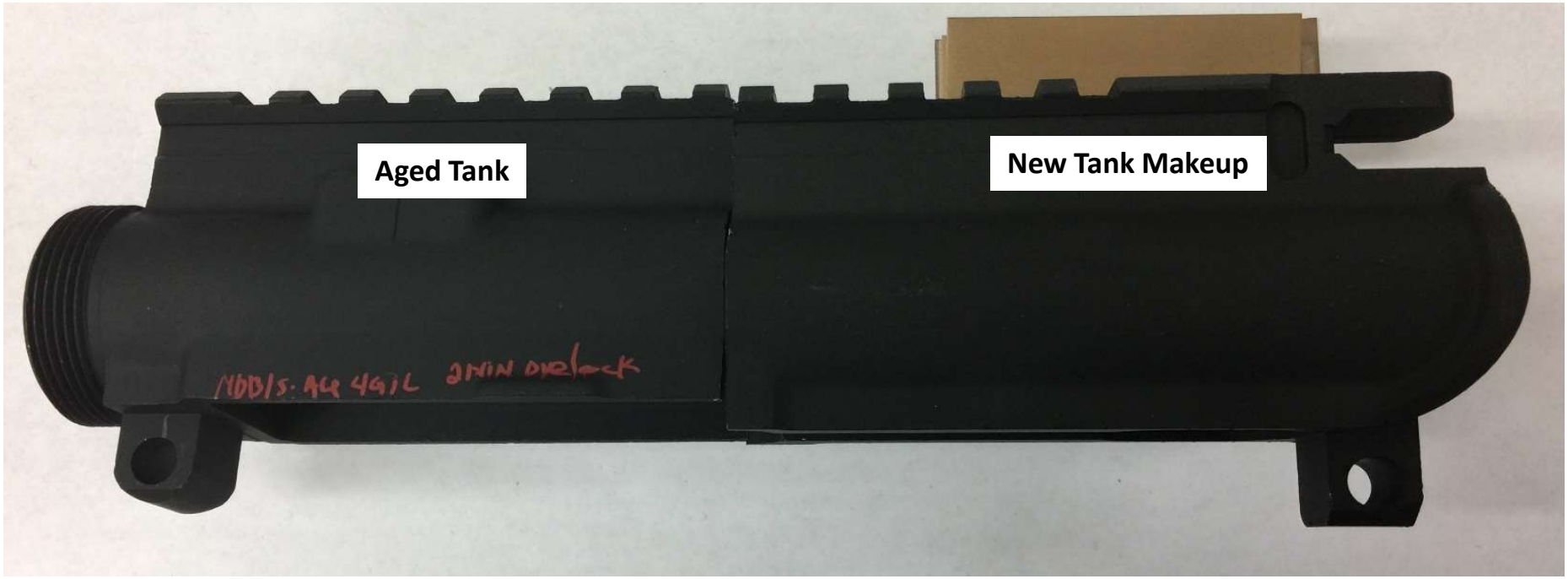
1. Mechanical Pretreatment
   - If the media blasting is not uniform the part can show a wavy pattern
   - If the media has broken down and not replenished at the appropriate time the finish will have a different appearance.
2. Chemical Pretreatment
   - Too short of an etch will leave the end product less deep in color and will mar very easily.
   - Too long of an etch will make the part more reflective and might bring out the grain in the material.

Common Issues/Challenges: Inconsistent Finish

2 min - Etch with marring

4 min -Etch with less marring

Common Issues/Challenges: Inconsistent Color



- The part on the left had effective dye concentration of 80% whereas the part on the right had effective concentration of 95%.
- This image indicates the importance of dye tank maintenance over a prolonged period of time.

Common Issues/Challenges: Galvanic Corrosion

- Occurs when dissimilar metals come in contact under a conductive/oxidative environment.
- Common problem when titanium tooling is used on 2000, 7000 series aluminum or when there are surface imperfections on wrought alloys
- There are a few techniques that can be used to reduce the risk of Galvanic when anodizing
  - Increase the pH of the dye tank
  - Reduce dye time if possible
  - Check for chloride contamination in dye tanks
  - Change the dye that is used since some dyes have residuals chlorides from the salting/manufacturing process

Final Thoughts/Considerations

- As a whole the processing of firearm components has a variety of challenges that make achieving an ideal finish critical for the end customer.
  - The **firearm component processing requirements are very demanding** and therefore are crucial in providing an end product that can be operated reliably and successfully in the field.
  - The **specification for the anodic finish is does not include the entire process** and therefore **many anodizers use different processing conditions** to achieve a finish that meets the requirements of their customer
  - The **firearm supply chain is complex and includes a multitude of vendors**. This means that different vendors can machine or process the same parts prior to arrival at the anodizer which can create issues for anodizing these components
- When troubleshooting issues associated with armament components it is important to focus on the entire process and not just the black dye and seal process.
- If the pretreatment process is well established and repeatable and components become inconsistent, then factors such as the choice of dye, effect of contaminants, apparent and effective dye concentration and sealing method must be considered.

References

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Questions